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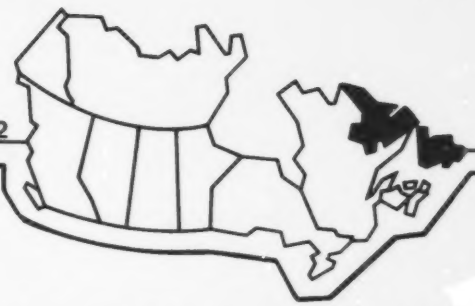
Growth and Development of Exotic Tree Species in Newfoundland

J. Peter Hall
Newfoundland Forest Research Centre

N-X-212



Eastern U.S.A. and Canada
- Jack Pine
- Red Spruce
- Eastern White Cedar
- Hemlock
- Black Locust

United Kingdom
- Scots Pine
- Hybrid Larch

U.S.S.R.
- Siberian Larch

Japan
- Japanese Larch
- Hondo Spruce
- Oriental Spruce
- Japanese Birch
- Sugi
- Veitch's Fir
- Japanese Black Pine

British Columbia
- Western White Pine
- Lodgepole Pine
- Whitebark Pine
- Sitka Spruce
- Englemann Spruce
- Douglas Fir
- Western Red Cedar

Scandinavia
- Norway Spruce
- Scots Pine

Europe
- Austrian Pine
- Black Pine
- Serbian Spruce
- European Larch
- European Birch

89-00151/

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GROWTH AND DEVELOPMENT OF EXOTIC TREE SPECIES IN NEWFOUNDLAND

by J. Peter Hall

INFORMATION REPORT N-X-212

1982

NEWFOUNDLAND FOREST RESEARCH CENTRE
CANADIAN FORESTRY SERVICE
ENVIRONMENT CANADA

C Minister of Supply and Services Canada 1982

ISSN No. 0704-7657
CAT No. Fo 46-15/212E
ISBN NO. 0-662-12311-5

Copies of this report are available from:

Newfoundland Forest Research Centre
Canadian Forestry Service
Box 6028, St. John's, Newfoundland
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ABSTRACT

A series of trials of exotic tree species throughout Newfoundland over a 30-year period has identified species comparable to native species in terms of growth and adaptation to the Newfoundland environment. The most successful exotics have been Japanese and European larch with less success with Sitka spruce, Norway spruce, Veitch's fir, Scots pine and jack pine. Approximately 30 other conifers and four angiosperms have been tested but were inferior to native black spruce and white spruce in growth and ability to survive.

The major reasons for the exotic species trials were to afforest barren sites in eastern Newfoundland, to find species which would outgrow native ones on forested sites, and be resistant to damaging insects. Thus the exotics are compared to native black spruce and/or white spruce growth and development on similar sites and their suitability assessed on this basis.

RESUME

Après 30 ans d'essais dans l'ensemble du territoire de Terre-Neuve, on a déterminé les essences exotiques qui se comparaient aux essences indigènes par la croissance et l'adaptation au milieu. C'est avec les mélèzes japonais et européens qu'on a obtenu le plus de succès; l'épinette de Sitka, l'épinette de Norvège, le sapin de Veitch, le pin écossais et le pin gris ont donné de moins bons résultats. Les essais ont aussi porté sur une trentaine d'autres conifères et quatre angiospermes, mais leur croissance et leur aptitude à survivre étaient inférieures à celles de l'épinette noire et de l'épinette blanche indigène.

On a introduit les espèces exotiques surtout pour reboiser les terres improductives de l'est de la province et pour trouver les essences qui pourraient supplanter les arbres indigènes dans les régions boisées, et résister aux insects ravageurs. On compare donc la croissance et le développement des essences exotiques avec le rendement des arbres indigènes, l'épinette noire ou l'épinette blanche, dans des stations similaires, et on détermine ainsi les essences qui sont appropriées.

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GROWTH AND DEVELOPMENT OF EXOTIC TREE SPECIES IN NEWFOUNDLAND

by

J. Peter Hall

I. INTRODUCTION

Trees which are moved outside their natural range are termed exotics. In reforestation programs they are usually introduced because of some failing with the native species; either the native species cannot supply the needs of the forest industry or they have severe insect or disease problems. Failure of native species to fulfil an economic need is illustrated in several countries. In the United Kingdom the only native species, oak (Quercus robur L.), Scots pine (Pinus sylvestris L.) and yew (Taxus baccata L.) were insufficient in quantity and quality of fibre to meet demands of the forest industry and so several new species were introduced. These included Sitka spruce (Picea sitchensis Bong. (Carr.)) and lodgepole pine (Pinus contorta Loud) from British Columbia and Japanese larch (Larix kaempferi Lam. (Carr.)) from Japan. In New Zealand native species consisting primarily of slow-growing hardwoods were unsuitable as reforestation species and so were replaced primarily by Monterey pine (P. radiata Don.) which originates from a small area in southern California. In Newfoundland the native species meet the demands of forest industries for fibre. The introduction of exotics was begun in order to determine if there were other species which would yield more fibre and consequently have greater economic value than native species. The native conifers, apart from the spruces, are largely unsuitable for reforestation. For example, white pine (Pinus strobus L.) is damaged by the white pine weevil (Pissodes strobi Peck.) and the white pine blister rust (Cronartium ribicola Fisch.). The most common conifer in Newfoundland, balsam fir (Abies balsamea L. (Mill.)) is not considered for reforestation because it is highly vulnerable to attack and subsequent mortality by the spruce budworm (Choristoneura fumiferana Clem.), the hemlock looper (Lambdina fiscellaria fiscellaria Guen.) and the balsam woolly aphid (Adelges piceae Ratz.).

In Newfoundland the cool humid climate coupled with glaciated topography has resulted in development of many lakes and bogs and upland soils consisting of humo-ferric and ferro-humic podzols of low to medium fertility. Most soils are moist and frequently inadequately drained and even well-drained soils have more moisture in the growing season than is required for plant growth.

The species composition of Newfoundland's forests is also typical of boreal forests (Rowe 1972). The dominant species are black spruce (Picea mariana Mill. (BSP)), white spruce (P. glauca Moench (Voss)) and balsam fir which together comprise 87% of the merchantable volume of the forests (cf Khalil 1972). White birch (Betula papyrifera Marsh.) forms another 10%, tamarack (Larix laricina Du Roi (K. Koch)), 2%; white pine and red pine (P. resinosa Ait), 1%. Other species with scattered distribution and negligible volume are yellow birch (Betula allaghaniensis (Brit.) Ashe), aspen (Populus tremuloides Michx.), balsam poplar (P. balsamifera L.) and red maple (Acer rubrum L.). Only the spruces, balsam fir and white birch are harvested commercially.

Black spruce is the most desired species in Newfoundland because its dense wood and long fibres are ideal for the manufacture of newsprint. It has few insect or disease problems, is easy to establish by planting or seeding but it is slow growing. The quantities of black spruce are declining because of heavy cutting and fire losses. Black spruce stands often regenerate poorly following cutting; natural regeneration is most successful following wildfire.

Balsam fir is the most abundant conifer and the most valuable economically. However, as stated, it is vulnerable to attack by a number of forest insects and when epidemics occur, forest losses can be severe over extensive areas. Balsam fir, because of its wood properties, is almost as valuable as black spruce for pulping and. in addition, it is an important species for lumber. It grows faster than black spruce and reproduces in large quantities following clearcutting.

White spruce, potentially a valuable species, is too scarce to have a great economic importance. It grows rapidly, is good for paper making and for lumber, and like balsam fir, is susceptible to attack by forest insects though to a lesser extent.

Tamarack occurs as a scattered tree in spruce and fir stands and is usually harvested with these species. It is the fastest growing of the native conifers but seed for growing stock is difficult to obtain. Tamarack is attacked by the larch sawfly (Pristiphora erichsonnii Hart.), the larch casebearer (Coleophora laricella Hubner) and the eastern bark beetle (Dendroctonus simplex LeConte) (Schooley and Pardy 1981). It may be defoliated by the spruce budworm and hemlock looper but since a new crop of foliage is produced annually these effects may not be as severe as on balsam fir.

White pine and red pine occur in scattered stands or singly and are not used in the manufacture of pulp and paper in Newfoundland. The species are also attacked by insects and diseases and are not considered suitable as reforestation species. Pines throughout New-

foundland are damaged by the root collar weevil (Hylobius spp.). Damage is most severe in moist sites and tree mortality has been extensive in many plantations, especially on the Avalon Peninsula (Warren and Parrott 1965).

The hardwood species occur in such low volumes that they have little commercial value. White birch, the most abundant, is used for firewood and for construction.

II. CHOICE OF SPECIES FOR INTRODUCTION

The choice of species for introduction is based upon the type of trees desired locally and on how successfully they can be grown in our boreal forests.

Trees which have good growth and wood quality usually grow well under similar environmental conditions elsewhere. Species generally found 35°-55° N (further north is Scandinavia) and at elevations below 3 000 metres merit examination for Newfoundland (Table 1). Since most tree species are variable within their natural range, it is also necessary to test provenances from different parts of the natural range. For example, for species with a small natural range such as Japanese larch only two or three provenances would be tested whereas for those with a wide range such as Scots pine, several seedlots should be tested. It is also necessary to plant local species with the exotics for direct comparison of results and wherever possible this has been the procedure followed in trials of exotic species in Newfoundland.

This paper describes various trials of exotic species undertaken in Newfoundland over the past forty years. It includes a brief historical review of the planting of exotics, the development of plantations established by the Newfoundland Government between 1938 and 1952, and of studies conducted by the Canadian Forestry Service (CFS) between 1952 and 1980.

III. HISTORICAL DEVELOPMENT

Forest exploitation in Newfoundland began early in the seventeenth century when fishing settlements were established on the Avalon Peninsula. Widespread and indiscriminate cutting occurred as trees were harvested for firewood, boat building, construction of dwellings, fish flakes etc. Large areas of forest and scrub were also burned, a practice which although deplored by the early authorities resulted in the extensive barren heathlands common to eastern Newfoundland. This type of forest use spread with the gradual settlement throughout coastal Newfoundland in the eighteenth and nineteenth centuries. It was not until early in the twentieth century, when the pulp and paper mills were established, that large-scale commercial harvesting began.

Table 1. Exotic tree species which have been tested in Newfoundland.

Scientific name	Common name	Natural range
Pinus banksiana	Jack pine	Boreal Forest Canada
" monticola	Western white pine	B.C. southern California
" contorta	Lodgepole pine	Alaska to N. Mexico
" albicaulis	Whitebark pine	B.C. to California, Rocky Mts.
" sylvestris	Scots pine	Europe east to Siberia
" nigra	Austrian pine	Central and Southern Europe, Asia Minor
" cembra	Macedonian pine	Southeastern Europe
" thunbergii	Japanese black pine	Japan and Korea
Picea rubens	Red spruce	E. Canada, N.E. U.S.A.
" sitchensis	Sitka spruce	Alaska to Calif., along Pacific Coast
" englemannii	Englemann spruce	B.C. to New Mexico to Rocky Mtns.
" abies	Norway spruce	Western Europe and western Russia
" omorika	Serbian spruce	Southeastern Europe
" orientalis	Oriental spruce	Caucasus and Asia Minor
" jezoensis	Hondo spruce	Manchuria east to N. Japan
Pseudotsuga menziesii	Douglas fir	Central B.C. to Mexico, Rocky Mtns.
Larix kaempferi	Japanese larch	Japan
" decidua	European larch	Europe
" eurolepis	Hybrid larch	Natural hybrid between L. kaempferi and L. decidua
" sibirica	Siberian larch	European Russia and western Siberia
Thuja plicata	Western red cedar	Central B.C. to California
" occidentalis	Eastern white cedar	E. Canada and N.E. U.S.A.
Tsuga canadensis	Hemlock	E. Canada and N.E. U.S.A.
Abies veitchii	Veitch's silver fir	N. Japan
" holophylla	Needle fir	Japan
" homolepis	Nikko fir	Japan
" mariesii	Maries fir	Japan
" mayriana	Saghalin fir	N. Japan
" sachalinensis	Saghalin fir	N. Japan, Saghalin, Kurile Is.
Cryptomeria japonica	Sugi	Japan
Robinia pseudoacacia	Black locust	Eastern United States
Betula verrucosa	European birch	Europe, Asia Minor
" ermannii	Japanese birch	Japan, N.E. Asia
" maximowicziana	Japanese birch	Japan

In 1938 a nursery was established at Salmonier on the Avalon Peninsula in eastern Newfoundland to produce seedlings for reforestation. Before plantable growing stock could be raised, a shipment of seedlings from Ontario, Dept. of Lands and Forests was received and outplanted near the nursery. The seedlings, Norway spruce, jack pine and red pine rapidly outgrew local seedlings of black spruce and balsam fir, and so, after 1940, seed for nursery production of seedlings consisted largely of these exotics. The nursery produced seedlings for outplanting continuously between 1938 and 1952. Annual production reached 1,000,000 trees by 1952. Most of the trees produced after 1945 were Scots pine with lesser amounts of red pine, jack pine and Norway spruce. Approximately 800 hectares were planted on the Avalon, Bonavista and Burin peninsulas at a spacing of 1.5 m. Following assessment of the reforestation program in 1952 the program was discontinued because of the failure of most of the plantations. This ended the active effort of the Provincial Government in the introduction of exotic species.

In 1950 the Government of Canada opened a District Forest Office in St. John's. One of the earliest studies was a test of several exotic species on four sites on the Avalon Peninsula.[1] Norway and Sitka spruce and Scots, jack, lodgepole and ponderosa pine were tested. Many of the plantations established by the Provincial Government were also evaluated in 1952.[2] Initial results with Sitka spruce and Scots pine were encouraging and led to their use in planting and seeding trials on non-regenerating burned sites and for afforestation on barren sites. They were also used to reforest areas burned intentionally to remove balsam fir regeneration as part of stand conversion studies.

In 1964 a study was established in western Newfoundland to test several Asian species of fir (Abies spp.) for resistance to attack by balsam woolly aphid and also to compare their growth rate with that of balsam fir. In 1963-65 seeds of various species from several origins were grown in a newly established nursery at North Pond in east-central Newfoundland. Between 1967 and 1972 these species were outplanted in unreplicated plots in eastern, central and western Newfoundland. Between 1966 and 1971 a provenance trial of Sitka spruce was established. Most of the planting in the late 1960's took place on burned cutovers or on prepared forest sites which had supported productive forest. A few trials were established on various peatland sites e.g. slope bogs, dome bogs, plateau-raised bogs and slope fens. Plantations were also established on ploughed heathlands on the Avalon Peninsula.

Increased interest in the potential of various Populus hybrids for eastern Canada led to the establishment of a clonal trial of native and exotic poplars in western Newfoundland. Also as a result of successes

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[1] Lewis, H.S. 1952(a). Direct comparison of various species and classes of planting stock on non-forested areas. Can. Dept. Res. and Devel., For. Br., Nfld. Dist. 9 p.

[2] Lewis, H.S. 1952(b). Single examination of provincial government plantations. Can. Dept. Res. & Devel., For. Br., Nfld. Dist. 28 p.

with various species of Larix a species trial of Japanese, European, hybrid and Siberian larch and tamarack was established in 1976. Early encouraging results from this trial suggest that further introduction and tests of larches would be worthwhile.

The objectives of exotic species introductions in Newfoundland have changed over the years based on the results and assessments of the various trials. The planting of Scots and jack pine and Norway and Sitka spruce in the 1940's followed their apparently successful introduction in 1938. After assessing these species in 1952 it was decided to continue to use them in larger reforestation trials. Tests of Japanese larch, Douglas fir, red spruce, lodgepole pine, ponderosa pine and red pine were also initiated. Red pine is not an exotic but occurs in a few stands in Newfoundland as a relict. By 1966, trials of most species of exotics which could be expected to survive in the Newfoundland climate had been established. As results of the trials became available, emphasis was placed on intensive testing of the more promising species -- Sitka spruce and the larches.

IV. METHODS

A. Establishment of Plantations

The first group of large-scale plantations was established in eastern Newfoundland between 1938 and 1952 using 2 + 2 bareroot stock. The seedlings were planted by the pit planting method (Smith 1962) at a 1.5 m spacing, resulting in a stand density of 4400 stems per hectare. These plantations were composed of several species and ranged in size from 1.6 to 161.9 ha.

Plantations established between 1952 and 1965 used imported seedlings from both the Acadia Forest Experiment Station in central New Brunswick and the Petawawa National Forestry Institute at Chalk River, Ontario. All seedlings were 2 + 2 bareroot stock. The seedlings were planted by the pit method at a spacing of 1.8 to 2.0 m resulting in a density of 3090 to 2500 stems per hectare. These plantings were established to study reforestation methods using both exotics and native species.

Beginning in 1965 planting stock for species and provenance trials was grown in the CFS nurseries at North Pond and Pasadena. Several age classes of bareroot stock, ranging from 2 + 0 to 2 + 4, were produced. Planting was by the pit method on mineral soils and by the slit method on peat soils (Hall 1971a). Seedling spacing was 2.0 or 2.4 m resulting in densities of 2500 to 1740 stems per hectare.

Several direct seeding trials were established in the 1960's using Sitka spruce, Norway spruce and jack pine in tests of reforestation

methods. Trials of broadcast seeding on various sites were established using 123 500 seed per hectare. Seedspotting ten viable seeds per spot, spaced at 2.0 m (2500 spots per hectare), was also used widely.

B. Assessing the Suitability of Exotic Species

Smith (1962) states that "natural genotypes have met the test of survival in the locality for at least thousands of years and are thus highly dependable in meeting the rigors of the future". The indigenous species therefore have an inherent environmental advantage over exotics. Thus, any exotic must substantially outgrow the native species if it is to be used in reforestation programs. This is necessary to compensate for the increased risk associated with a different environment (Wright 1976).

In addition to rapid rates of growth exotic species must also be as easy to establish as native ones and must also remain as free from insect and disease pests as native species. Moreover, the exotic species must produce wood of acceptable quality for the existing conversion plants. Thus in order to be acceptable as a reforestation species an exotic must be evidently superior to the native species.

In many parts of the world where exotics are extensively planted, their suitability depends on their intrinsic merits because the native species were unsuitable for reforestation. In Newfoundland, however, native species fulfil our principal economic need. The suitability of exotics in Newfoundland is, therefore, based on a comparison with the growth of native species. Suitability is based on an ability to survive and grow as well as or better than exotics.

V. RESULTS AND DISCUSSION

A. Plantations Established Between 1938 and 1952

As planting stock became available from the Salmonier nursery seventeen plantations were established in eastern Newfoundland. Sixteen of these were in eastern Newfoundland (Figure 1) - fourteen, on barren heathlands; one, at Salmonier, on a previously forested site; and the other, near Terra Nova, on a site which had been cut and burned twenty years before planting. One plantation was located on a previously forested site near Howley in western Newfoundland (Figure 2). Table 2 lists the plantations, location, date of establishment, species composition, estimated size and results of the first assessment. No data are available on the percentage species composition. Of the 17 plantations 11 were classed as failures - meaning no merchantable trees would be formed - and two as successful.[3] In the remainder, which were partially successful,

[3]Doyle, J.A. 1967. Report of Reforestation in Newfoundland. Unpub. Report. 27 p.

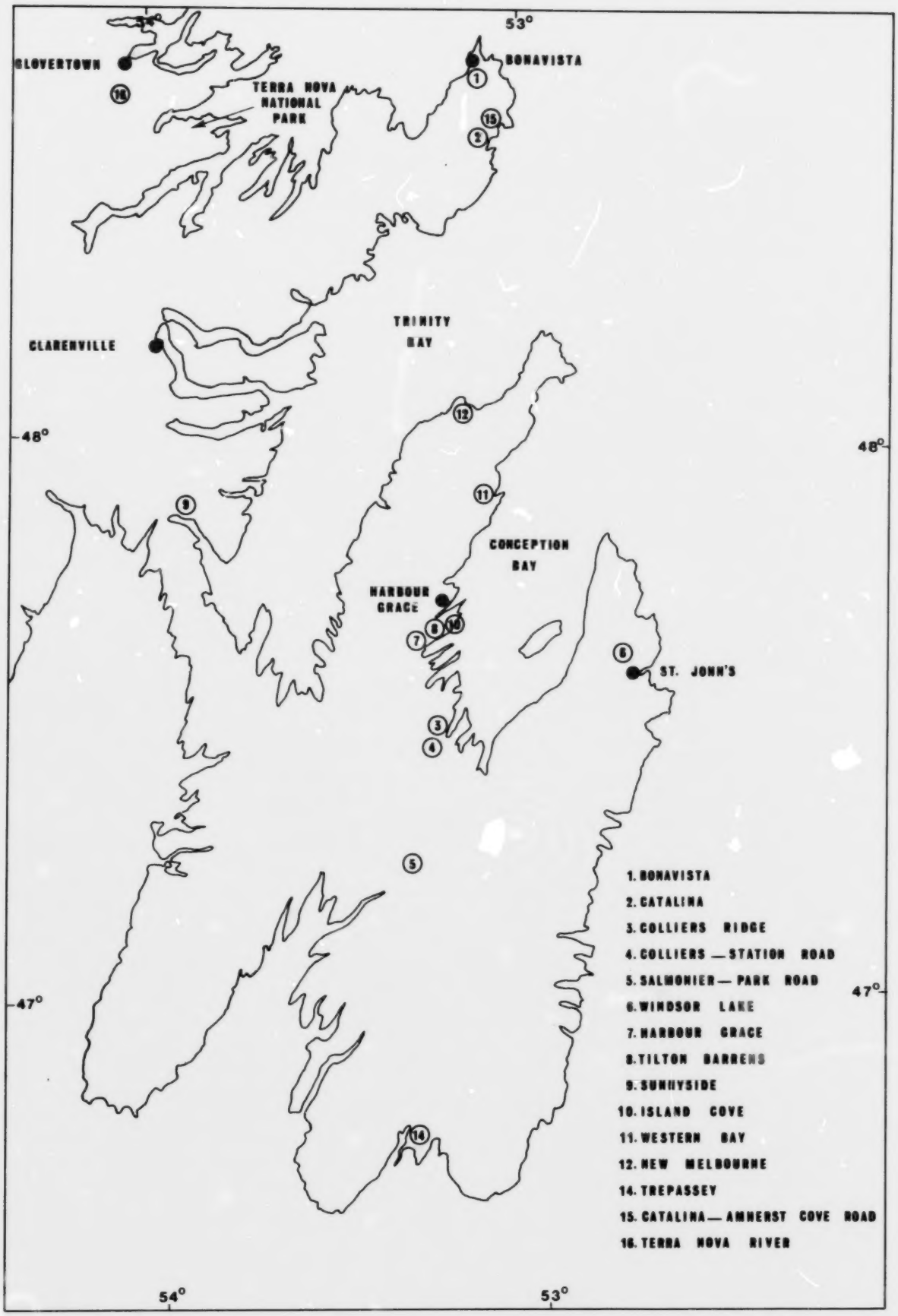

FIGURE 1. AVALON AND BONAVISTA PENINSULAS SHOWING LOCATIONS OF PLANTATIONS.

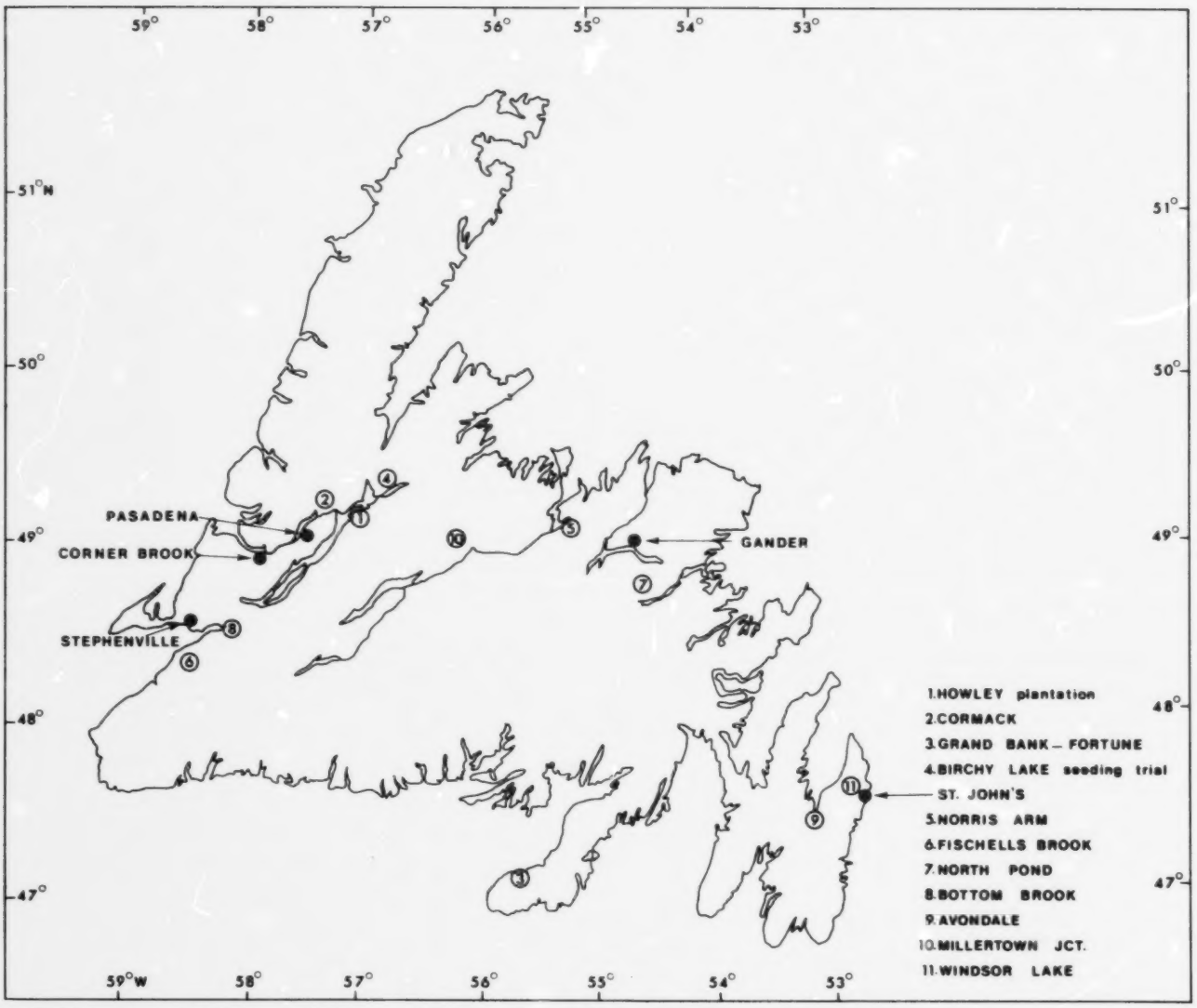

FIGURE 2. NEWFOUNDLAND SHOWING LOCATIONS OF EXOTIC SPECIES PLANTATIONS

Table 2. List of plantations established 1938-1952.

Plantation number	Location	Date(s) established	Species planted	Area planted (hectares)	Result of 1952 examination
1	Bonavista	1944, 1945, 1950	Scots pine, jack pine, white pine, Norway spruce	22.4	Failure
2	Catalina	1944, 1945 1950	Scots, jack, red, white pine, Norway spruce white spruce	32.3	Failure
3	Colliers Ridge	1944, 1949	Scots, jack, red pine, red, white spruce	24.3	Partial success
4	Colliers Station Road	1947, 1949 1951	Scots, jack pine, Norway spruce	26.7	Failure
5	Salmonier	1938	Scots, jack, red pine, red spruce	24.3	Successful
6	Windsor Lake	1947, 1948	Scots, jack pine	16.9	Partial success
7	Harbour Grace	1949, 1950	Scots, jack, red pine	85.0	Failure
8	Tilton Barrens	1949, 1950	Scots, jack, red pine	46.2	Partial success
9	Sunnyside	1950	Scots pine	46.2	Failure
10	Island Cove	1950	Scots, jack, red pine	47.6	Failure
11	Western Bay	1950	Scots, jack, red pine	161.9	Failure
12	New Melbourne	1950	'Various pines'	19.6	Failure
13	Grand Bank. Fortune	1951	Scots, jack pine	68.8	Failure

Cont'd ...

Table 2. (Concl'd.)

Plantation number	Location	Date(s) established	Species planted	Area planted (hectares)	Result of 1952 examination
14	Trepassey	1951	Scots pine	46.2	Failure
15	Catalina	1949	Scots, jack pine	71.1	Failure
16	Terra Nova	1949, 1950	Jack, red pine	3.5	Successful
17	Howley	1950, 1951	Jack, red pine Norway spruce	1.6	Partial success

it was assumed that parts of the plantation would eventually form a merchantable stand. Exposure to wind, sleet, ocean spray, frost upheaval on thin or wet soils, and, in some cases, severe grazing by sheep and goats were the major limiting factors affecting plantation survival. Thirty years after planting only a few stunted scraggly stems were found in most areas.[3] It was apparent that the only successful plantations were those located on sites which were sheltered from winds off the sea and which had relatively deep, stone-free and well-drained soils. On areas where partial success was observed, exposure was less severe thus allowing parts of the stand to develop.

Measurements of height and survival were made at various stages of development between 1952 and 1982 (Table 3). Local species were seldom planted with the exotics but it is possible to compare the height of the exotics with that of native black spruce and balsam fir using height/age curves for eastern Newfoundland (Page and van Nostrand 1970) (Table 3).

Comparing these with the measurements from the plantations it is apparent that growth of the exotics is generally as good as and in many instances better than could be obtained from local spruce or fir. At Salmonier all pines were superior. At Colliers Ridge only jack pine was taller than local spruce or fir. It would be unwise to carry the comparison too far because the data compiled for natural stands were based on forested sites whereas most of the plantations were on barrens. Furthermore, the spruce and fir data are an average of several forested site types. In the sheltered plantations at Terra Nova and Howley, on previously forested sites, growth is faster than on the barrens. The height of 7 to 8 m at Terra Nova and 6 m at Howley are comparable to growth obtainable with black spruce.

Table 3. Survival and height in 'successful' plantations established between 1938 and 1952 and growth of native spruce and fir (from ht./age curves).

Location of plantation	Species	First measurement				Second measurement			
		Age[1]	Survival	Height[2]	Diameter[3]	Age	Survival	Height	Diameter
Salmonier	Scots pine	14	> 90%	4.11	7.4	45	-	12.0	13.8
	jack pine	14	"	3.96	6.7	-	-	-	-
	red pine	14	"	2.74	5.1	-	-	-	-
Terra Nova	jack pine	32	> 90%	8.09	10.1	-	-	-	-
	red pine	32	"	7.31	9.9	-	-	-	-
Colliers Ridge	Scots pine	12	-	1.35		38	54.7	8.46	12.2
	jack pine	12	-	1.27		38	56.7	5.87	9.0
	white spruce	-	-	-		38	-	4.67	9.4
	red spruce	-	-	-		38	-	5.57	10.2
Windsor Lake	jack pine	8	87	0.69	-	32	15	6.43	11.7
Tilton Barrens	Scots pine	32	62.3	6.56	12.2	-	-	-	-
	jack pine	32	57.4	6.01	9.7	-	-	-	-
	red pine	32	39.6	5.74	9.6	-	-	-	-
Howley	jack pine	32	> 90%	5.93	12.2	-	-	-	-
	red pine	32	"	6.05	13.8	-	-	-	-

Growth of native	Age				
	12	14	31	32	38
black spruce	2.1	2.3	4.9	6.1	6.4
balsam fir	2.4	2.6	6.7	7.0	7.9

[1]Age - total age from seed.

[2]Height - average total height in metres.

[3]Diameter - at 1.4 metres above ground in centimetres.

Jack pine was measured on three sites at Colliers Ridge. Exposure strongly affected both height growth and survival. The average height in the lower, most sheltered site was 6.92 m; the middle, of average exposure 4.60 m; and the upper, most exposed, 2.30 m.

Trees at both Salmonier and Terra Nova River were nearly always well formed with few forked or crooked stems. At other areas, where exposure was greater, only one-quarter or fewer of the stems were well-formed. The exception was the planted red spruce at Colliers Ridge which were nearly all well-formed. Forked or crooked stems occurred on up to three-quarters of the planted pines. This defect is attributed to exposure, snow damage or grazing in the early stages. Studies by Nickerson (1968) showed that many of the sites were too exposed to winds to be suitable for growing trees. Exposure has strongly affected survival, growth, stem form and development.

In summary, planting of exotic pines on the barren lands of eastern Newfoundland had little success. The poor survival and growth was attributed to the harsh environment in which they were planted. In more favourable environments at Salmonier and Terra Nova the exotics grew well. Growth at the Howley plantation was poor because the area was completely exposed to winds and high snowfalls both of which caused stem and branch breakage. At sites on the Avalon Peninsula, pines were severely attacked by the root collar weevil which has caused extensive mortality in many plantations thus making pine an unsuitable plantation species except on the driest of sites (Warren and Parrott 1965).

B. Plantations Established Between 1952 and 1960

The results of the early plantations showed some promise for both Scots and jack pine. In 1952 the CFS established a species trial with Scots and jack pine plus ponderosa and shore pine and Norway and Sitka spruce. The plantations were established near the four plantations described previously: Colliers Ridge (#3), Trepassey (#14), Harbour Grace (#7) and Sunnyside (#9)(Figure 2). At each area three sites of maximum, average and minimum exposure were planted. Survival counts were made after the first growing season and all dead trees were replaced. Survival and height data were collected five and ten growing seasons after establishment. Overall mortality was about 20 percent after one growing season, half of which was attributed to grazing damage (Table 4). Consequently, the sites were fenced the following year. The small size of the trees when planted may have reduced the chances of survival and the replacements (mostly 2 + 1) probably had a better chance of surviving than the original trees. Norway and Sitka spruce had the best survival followed by Scots pine. Ponderosa pine, shore pine and jack pine had poor survival and could not be considered suitable species for reforestation. The best height was in Scots and jack pine

Table 4. Survival and height of various exotics planted on four sites on the Avalon Peninsula, 1952.

Species	Origin	Age[1]	Percentage survival			Avg. total height (m)	
			1[2]	5	10	5	10
Jack pine	Ontario	2-0	64.7	55.1	44.9	.61	1.30
Jack pine	Ontario	2-2	78.6	76.9	67.6	.74	1.39
Scots pine	Baltic	2-0	79.6	86.6	76.9	.58	1.27
Scots pine	Scotland	2-0	86.7	78.7	71.3	.66	1.38
Scots pine	Ontario	2-0	81.8	77.8	67.6	.69	1.48
Ponderosa pine	-	2-0	73.4	34.7	13.4	.46	.87
Lodgepole pine	-	2-0	75.3	70.8	52.8	.53	1.12
Norway spruce	-	2-2	84.3	91.7	87.5	.51	1.00
Sitka spruce	-	2-0	83.2	87.5	82.4	.43	.94
Plantation							
Colliers Ridge	-	-	91.4	74.1	64.0		
Trepassey	-	-	82.1	83.7	72.8		
Harbour Grace	-	-	79.0	65.0	57.0		
Sunnyside	-	-	66.9	70.2	57.0		

[1]Age class when planted.

[2]No. of growing seasons since planting.

and poorest in the spruces. If establishment problems could be overcome (for instance 2 + 2 jack pine had 20% better survival than 2 + 0) then possibly both jack and Scots would be suitable for reforestation.

The plantation with the best survival was at Trepassey; with Harbour Grace and Sunnyside the poorest. In each plantation the sites with the best survival were those with the least exposure. It is possible that more successful establishment might have resulted from larger plantations where greater protection would be provided by surrounding trees.[4] Observations in 1978 indicated that survival of previously measured trees was good and that well-formed trees were found on the least exposed locations.

[4]Wilton, W.C. 1957. Direct comparison of various species and classes of planting stock on non-forested areas. Can. Dept. Nor. Aff. and Nat. Res., Forest. Br., St. John's, Nfld. Unpub. File Rep. 25 p.

The next plantation trial of exotics in Newfoundland was established in 1955 at Torbay, near St. John's on a non-forested site which had been pre-treated by spraying with herbicides and scarifying with hand tools.[5] Earlier observations indicated that if site conditions were improved seedling establishment and subsequent growth would be better than that achieved in earlier trials. Red pine, Norway spruce and Sitka spruce were planted over an area of approximately 1.7 ha and were given several fertilizer treatments.[5] Early survival was excellent in the plantation with over 80% of all species surviving for the first five years (Table 5). Much of the later mortality, especially of red pine, occurred because of unauthorized cutting of Christmas trees. Growth was poor averaging less than 2 m in 18 years (Table 5). Many of the trees were damaged by root collar weevils and Armillaria root rot at age 18 (Warren and Singh 1970).

Site conditions are extremely variable in the plantation and though on some areas height is 2.5 to 3.0 m, the wet conditions have resulted in poor rates of growth.[6] In 1981 all of the red pine trees were killed by the European strain of Scleroderris canker (Gremmeniella abietina (Lagerb.) Morelet) and have since been destroyed.[7]

Table 5. Survival and growth of planted exotics in Torbay plantation.

Species planted	Percentage survival		Avg. total ht. of trees 18 years from seed (m)
	4 growing seasons	15 growing seasons	
Norway spruce	94	96	1.39
Sitka spruce	88	63	1.68
Red pine	83	63	1.81

[5]Wilton, W.C. 1958. Preliminary trials of herbicides, fertilizers and mechanical disturbances to improve well drained heath soils. Can. Dept. Nor. Aff. and Nat. Res., Forest. Br., St. John's, Nfld. Unpub. File Rep. 18 p.

[6]Hall, J. Peter. 1970. Results of 1969 remeasurement of red pine plantation at Torbay. Can. Dept. Fish. and Forest., Can. For. Serv., St. John's, Nfld. Unpub. File Rep. 17 p.

[7]Hudak, J. 1981. Scleroderris canker destroys pine plantation. Woody Points, Vol. 10, No. 7. Nfld. For. Res. Centre.

In 1958 a plantation was established in western Newfoundland near Cormack (Figure 2). The site was a burned cutover on productive forest land which had not regenerated. Several exotic conifers aged 2-0 and 3-0 and locally occurring black spruce and white spruce wildlings were planted. Survival was better for local spruces than exotics (Table 6) indicating that exotics were unsuitable for planting. Japanese larch had the lowest survival but over the 10-year period fewer trees died than for the other species. While height growth of Japanese larch was superior to all other exotic species it was less than that for local spruces. Except for Norway spruce and Japanese larch the incidence of Armillaria root rot was also greater on exotics than on local spruces. The slower growth rates of the exotics may be explained by the small size and poorer root development of the seedlings used. Subsequent studies have shown that 2-0 or 3-0 seedlings have poorer survival than those which have been grown for a year or two in transplant beds (Hall 1979). It is probable, therefore, that the exotic species would have performed better if older planting stock had been used.

Table 6. Survival, height and incidence of disease in Cormack plantation.

Species	Origin	Age of seedlings	Percent survival			Average total height[2]	Percentage diseased[3]
			1[1]	4	10		
Sitka spruce	Lillisnoo, Alaska	2-0	82.5	77.5	70.0	0.98	34.3
" "	Queen Char. Is., B.C.	3-1	92.5	86.3	61.3	1.40	67.1
" "	Petersburg, Al.	3-0	81.9	76.9	48.1	1.07	37.6
" "	Old Sitka, Al.	3-0	88.1	84.4	65.1	1.22	42.5
" "	Fisk Bay, Al.	2-0	81.3	70.0	56.3	0.88	19.9
Norway spruce	Norway	2-0	85.6	75.0	69.4	1.28	12.8
Douglas fir	Vancouver Is.	2-0	86.3	69.4	46.9	0.88	30.5
Japanese larch	Holland	2-0	22.2	17.8	17.2	1.58	4.5
White spruce	Alaska	2-0	81.7	68.3	53.2	1.74	13.5
"	Cormack	-[4]	92.5	80.4	71.1	2.68	19.9[5]
Black spruce	Cormack	-				2.13	

[1]No. of growing seasons after planting.

[2]Height measured 10 years after planting.

[3]Percentage infection of Armillaria mellea 10 years after planting.

[4]Trees estimated to be 3-4 years old.

[5]Data combined for local spruce.

On the basis of these results it was concluded that black spruce and white spruce should be the principal species for reforestation under similar site conditions in western Newfoundland.

It can be further concluded that while most of the exotics were more difficult to establish than native species, not all difficulties could be attributed to the fact that they were exotics. Planting stock had not always been handled carefully and some seedlings were under-developed when lifted from the nursery. These factors can all be avoided by improving cultural and handling practices. Some exotic species such as Scots and jack pine grew as fast as or faster than native species. Norway and Sitka spruce grew slower than native ones. Red pine grew well on the drier sites and was less vulnerable to attack by root collar weevil. Ponderosa pine, lodgepole pine and Douglas fir had poor survival and grew poorly. Variation among seed origins within jack and Scots pine showed the need for provenance testing to determine the full growth potential of species.

C. Trials of Exotics in Direct Seeding Trials

The poorly stocked areas of burned forest land on the Island led to studies in seeding as a cheap and effective reforestation method (Nickerson 1969). Earlier indications of success with several exotics in plantations led to their inclusion with black spruce and/or white spruce in trials to evaluate both broadcast seeding and seedspotting methods and seeding intensity.

One of the first trials was on a recently burned cutover near Birchy Lake (Figure 2). Stocking was best for natural regeneration; the exotics had stocking levels of about 20% less (Richardson 1970). Height of the exotics was compared with that of natural black spruce regeneration on the site (Table 7). Differences were not significant except where black spruce was significantly taller than red spruce. Armillaria root rot was also more common on exotics than on native species. In general no advantage was gained by using exotics in this study compared to local black spruce or white spruce regeneration. Other studies on prescribed burns in western Newfoundland at Fischells Brook and in central Newfoundland at Norris Arm also used red spruce and Sitka spruce with black spruce in seeding experiments (Richardson 1969). Results from these studies indicated that black spruce was easier to establish and grew faster than the exotics (Richardson 1969). Moreover, it was also concluded that native species rather than exotics should be used on similar sites (Richardson 1970).

In 1965 a burned cutover at North Pond was seeded using a mixture of jack pine from Ontario and local black spruce. Both species

Table 7. Percentage stocking and height development of exotic and natural regeneration at Birchy Lake.

Species[1]	Origin	Avg. total height (m) Seeded	Natural regeneration[2]	Percentage diseased[3]
Norway spruce	Nord, Norway	3.92	4.27	)
"	Brindal, "	3.75	3.67	) 10.6
"	Ledanger, "	4.72	4.60	)
Red spruce	Western N.S.	4.11*[4]	4.66*	0.0
Hybrid spruce[5]	Denmark	3.53	3.89	13.6
White spruce	Denmark	5.03	4.48	0.0

[1]Western red cedar, British Columbia was also seeded but did not regenerate.

[2]Comparison with natural black spruce regeneration on same site.

[3]Percentage infection by Armillaria mellea on exotics. Black spruce regeneration was not infected.

[4]Means on the same line followed by an asterisk are significantly different at the 0.95 level of probability (Students t-test, Steel and Torrie 1960).

[5]A natural hybrid between P. sitchensis and P. glauca.

were satisfactorily stocked even though the sowing density of black spruce was 7.6 times that of the jack pine. The jack pine has grown much faster than the black spruce - at five years it was 0.35 m compared to 0.20 m for black spruce (Richardson 1973). After 14 growing seasons the jack pine was 2.38 m tall and the black spruce 1.22 m.[8]

In 1962 and 1963 three recently clearcut balsam fir sites in western Newfoundland were seeded to Sitka and red spruce. The aim was to convert the site from balsam fir, which occupied the area as regeneration, to spruce. The attempt was a failure because of competition from the fir regeneration and from hardwood shrubs on the site. The surviving exotics grew about as well as native spruce and fir and it was recommended that local spruces be used in future stand conversion attempts (Hall 1971b, Hall and Richardson 1973).

From these studies it can be concluded that the exotic pines grew faster than local species; the exotic spruces at about the same rate. The pine was seeded on a site with no vegetative competition, unlike the exotic spruces, and this may explain its faster growth.

[8]J. Richardson, personal communication.

D. Trials of Exotics on Previously Forested Sites

Subsequent planting trials consisted of tests of exotic species and a provenance trial of Sitka spruce. In 1964 a study was established at three sites in western Newfoundland to determine if several Asian species of fir could grow under Newfoundland conditions and if they were resistant to the balsam woolly aphid.[9] The aphid had severely damaged the balsam fir forests of western Newfoundland and silvicultural control by stand conversion to a resistant species appeared to be a solution to the problem (Carroll and Bryant 1960). The plantations were established using 2 + 2 seedlings grown at Acadia Forest Experiment Station in New Brunswick. Balsam fir from central New Brunswick was also included. Survival was very low in two of the plantations because of vegetative competition and frost damage after two growing seasons. Data were collected thereafter only at Bottom Brook where site conditions and hence survival were better. Veitch's fir survived as well as balsam fir, the recent drop in survival occurred when the plantation was damaged during roadbuilding (Table 8). Height growth of two of the three strains of Veitch's fir was also similar to that of balsam fir.

Table 8. Survival and growth of balsam fir and exotic firs at Bottom Brook.

Species	Percentage survival				Average total height (m)				Percentage diseased[2]
	6[1]	13	17	20	6	13	17	20	
Abies homolepis	77.1	64.6	41.7	-[3]	.17	.51	.55	-	17.8
A. holophylla	31.2	20.8	2.1	-	.19	.54	.48	-	67.5
A. mariesii	47.9	41.7	31.2	-	.08	.26	.36	-	21.5
A. mariesii	35.4	25.0	18.8	-	.10	.20	.21	-	26.1
A. mayriana	47.9	45.8	35.4	-	.16	.64	.79	-	23.3
A. sachalinensis	66.7	45.8	43.4	-	.17	.57	.79	-	15.8
A. veitchii	87.5	83.3	60.4	-	.17	.43	.60	-	6.7
A. veitchii	97.9	97.9	95.8	81.3	.22	2.02	2.48	2.90	0.0
A. veitchii	89.6	87.5	83.3	70.8	.23	1.86	2.37	2.75	4.4
A. balsamea	*85.4*	*77.1*	*77.1*	*75.0*	*.25*	*2.01*	*2.47*	*2.88*	*4.8*

[1]Years from seed.

[2]Percentage infection by Armillaria mellea ten years from seed (Hall et al. 1971).

[3]Measurements discontinued on species which failed.

[9]Wilton, W.C. 1965. A test to determine the susceptibility of certain Abies species to balsam woolly aphid injury. Can. Dep. of Forest., Forest. Br., St. John's, Nfld. Mimeo 65-N-5. 9 p.

The native fir was damaged by balsam woolly aphid but the exotic Veitch's fir was not; even attempts to introduce the aphid to the trees were unsuccessful (Hall and Schooley 1981). Veitch's fir was damaged by the spruce budworm in the late 1970's but to a lesser degree than balsam fir. It was concluded that compared to balsam fir, Veitch's fir grew as well, was more frost resistant, was completely resistant to the balsam woolly aphid and was about as resistant to Armillaria root rot and spruce budworm.

This is an example of a successful introduction of an exotic to replace a local species which was not resistant to a serious insect pest.

In 1966 a plantation trial of exotic pines was established at North Pond to test the growth of several species which had shown promise in earlier plantings (Figure 2). These included jack pine, Scots pine and lodgepole pine (Table 9). The trees were planted on a burned cutover which had little natural regeneration. No native spruces were planted for direct comparisons but some of the black spruce regeneration was sampled and a comparison has been made (Hall 1977b). Survival and height have been measured periodically to 15 years from seed (Table 9).

Scots, jack, lodgepole and red pine were successful on this site; the remainder were not. Jack pine grew the best of all the species followed by Scots and lodgepole pine. Red pine did not grow well largely because of the moist site conditions. Natural black spruce on the site was measured and found to be approximately the same height as the planted jack pine (Hall 1977b). From this it was concluded that only the jack pine merited consideration as a reforestation species on similar sites (Hall 1977b). However, wide variation in growth within the plantation indicates that Scots pine or lodgepole pine may succeed on specific sites.

The most extensive trial of exotic species was established between 1967 and 1972 in a series of unreplicated plots in western, central and eastern Newfoundland. The plantations consisted of one or more seedlots of each species with one hundred planted trees per plot. The planting stock was produced in the North Pond nursery; most stock was grown two years in the seedbeds and one to three years in the transplant beds before outplanting. Table 10 lists the species tested. Not all species were planted at each location. Because site histories and plantation development were different at each location the results from each are discussed separately.

Bottom Brook Plantation, Western Newfoundland. This plantation was established on a highly productive site which had been clearcut and then subjected to prescribed burning (Hall 1973). Vegetative competition

Table 9. Survival and growth of planted pines at North Pond.

Species	Origin of seed	Percentage survival				Avg. total ht. (m)			
		4[1]	7	12	15	2[2]	7	12	15
Scots pine	Morayshire, U.K.	97.0	97.0	96.3	96.3	.11	.73	1.73	2.50
Scots pine	Kuorevesi, Finland	95.8	94.9	93.2	93.2	.11	.67	1.68	2.70
Jack pine	North. Co., New Brunswick	96.2	95.7	94.2	93.6	.13	1.02	2.50	3.58
Lodgepole pine	Long Beach, Wash., U.S.A.	90.2	90.2	86.0	83.0	.06	.81	1.56	2.39
Red pine	Petawawa N.F.I., Ontario	79.7	77.9	75.9	73.9	.09	.43	1.14	1.84
Stone pine	St. John's, Newfoundland	74.3	69.4	55.9	-	.05	.12	0.34	-
Corsican pine	Sherwood, Notts., U.K.	63.7	59.4	26.5	-	.13	.39	0.49	-
Whitebark pine	Cranbrook, B.C.	73.7	45.6	7.1	-	.04	.13	0.36	-

[1]Years from seed. Stock was two years old when planted.

[2]Average height when planted.

Table 10. List of species tested in large scale species trials.

Scientific name	Common name	Newfoundland seedlot No.	Origin of seed
Pinus resinosa	red pine	14	Petawawa National Forestry Inst., Ont.
P. banksiana	jack pine	11	Northern Ontario
P. banksiana	jack pine	23	Newcastle, New Brunswick
P. contorta	lodgepole pine	18	Long Beach, Washington, USA
P. monticola	western white pine	36	Solsqua-Sicamous, British Columbia
P. sylvestris	Scots pine	51	Kuorevesi, Finland
P. sylvestris	Scots pine	55	Speymouth Forest, Scotland
P. sylvestris	Scots pine	47II	Hornes, Norway (these two
P. sylvestris	Scots pine	47III	are from single mother tree
P. sylvestris	Scots pine	48I	Landvik, Norway (these two
P. sylvestris	Scots Pine	48II	are from single mother tree
P. nigra var. austriaca	Austrian pine	92	Lower Austria
"	Austrian pine	107	Central Europe
"	Austrian pine	108	Southern Europe
"	Austrian pine	132	Denmark (Sennerup F-246)
P. nigra var. corsicana	Corsican	56	Sherwood Forest, England
Picea mariana	black spruce	25	Northumberland Co., N.B.
P. mariana	black spruce	59	West Branch Lake, Nfld.
P. glauca	white spruce	24	Guysborough Co., N.S.
P. rubens	red spruce	26	Northumberland Co., N.B.
P. sitchensis	Sitka spruce	4	Bella Coola, B.C.
P. sitchensis	Sitka spruce	29	Terrace, B.C.
P. sitchensis	Sitka spruce	33	Kitimat, B.C.
P. sitchensis	Sitka spruce	135	Kalum L., B.C.
P. englemannii	Englemann spruce	35	Kamloops, B.C.
P. omorika	Serbian spruce	60	Knuthenborg, Denmark
P. omorika	Serbian spruce	126	Germany
P. abies	Norway spruce	44I	Maridalen, Norway (from one mother tree)
P. abies	Norway spruce	46II	Senum, Norway (from one mother tree)
P. abies	Norway spruce	50	Vilppula, Finland
P. abies	Norway spruce	125	Germany
P. abies	Norway spruce	142	Germany
P. jezoensis	Hondo spruce	52	Tokyo Univ. Forest, Japan
P. orientalis	Oriental spruce	58	Svejbeck, Jutland, Denmark

Cont'd ...

Table 10 - Concluded

Scientific name	Common name	Newfoundland seedlot No.	Origin of seed
Pseudotsuga menziesii	Douglas fir	34	Shuswap L., B.C.
P. menziesii	Douglas fir	111	Central Europe
Larix laricina	tamarack (juniper)	27	Guysborough Co., N.S.
L. kaempferi	Japanese larch	129	Germany
L. kaempferi	Japanese larch	130	Germany
L. kaempferi	Japanese larch	139	Nagano, Honshu, Japan
L. decidua	European larch	102	Central Europe
L. decidua	European larch	134	Germany (Alpine)
Thuja occidentalis	eastern white cedar	113	Central Europe
T. plicata	western red cedar	112	New Zealand
Betula verrucosa	weeping birch	94	Southern Germany
B. ermannii	Japanese birch	137	Furano, Japan
B. maximowicziana	Japanese birch	157	Japan

on the site consisted of unburned dense patches of balsam fir seedlings and scattered white birch, trembling aspen and pin cherry (Prunus pensylvanica L.f.). Exotics consisting of various species of Pinus, Picea, Larix, Thuja and Betula were planted. One species each of Pseudotsuga and Tsuga were also planted. Remeasurements of height and survival were made periodically, the latest when the seedlings were aged 15 years from seed. Preliminary results five years after planting have been published (Hall 1973). Survival data show that although most mortality occurred early in the life of the plantation a few species died out gradually (Table 11). Some species can be eliminated from consideration based on poor survival. (Two species planted at Bottom Brook, black locust and Japanese black pine, are not included in Table 11 because they did not survive planting by more than two seasons.) Species with poor survival include western white pine, several black pine seedlots and Serbian spruce, Hondo and oriental spruce. The hemlock and Douglas fir from central Europe, and western red cedar from New Zealand were all unsuitable. The latter two species are exotics in

Table 11. Percentage survival 5 and 10 years after planting and average total height 15 years from seed of trees planted at Bottom Brook.

Species planted	Seedlot number	Percentage survival 5	Percentage survival 10	Average total height (m)
Red pine	14	86	84	2.35
Jack pine	23	95	94	4.03
" "	11	97	91	3.77
Lodgepole pine	18	82	77	3.55
Western white pine	36	73	47	2.62
Scots pine	51	97	95	3.48
" "	55	92	91	3.02
" "	48I	87	67	3.21
" "	48II	97	82	3.40
Austrian pine	92	-	77	2.19
" "	107	-	71	2.13
" "	108	-	59	2.45
" "	132	56	43	3.04
Corsican pine	56	47	31	1.72
Black spruce	59	-	84	2.87
" "	25	89	88	3.11
White spruce	24	78	72	2.46
Red spruce	26	98	92	2.93
Sitka spruce	4	-	57	1.80
" "	33	-	63	2.21
" "	29	91	85	3.19
" "	135	93	77	2.07
Englemann spruce	35	77	67	2.12
Norway spruce	44I	-	66	2.35
" "	46II	-	90	2.49
" "	50	-	88	2.62
" "	125	-	68	2.26
" "	142	-	83	3.12
Serbian spruce	60	-	77	1.87
" "	126	-	38	1.95
Hondo spruce	52	56	41	0.62
Oriental spruce	58	-	78	1.05
Douglas fir	34	59	53	2.10
" "	111	-	38	1.23

Cont'd ...

Table 11 - Concluded

Species planted	Seedlot number	Percentage survival 5	Percentage survival 10	Average total height (m)
Tamarack (juniper)	27	93	87	4.58
Japanese larch	129	72	63	4.97
" "	130	64	60	4.79
" "	139	62	53	5.31
European larch	102	73	70	4.72
" "	134	-	91	4.52
Eastern white cedar	113	-	89	1.21
Western red cedar	112	-	39	0.94
Eastern hemlock	123	-	35	0.87
European birch	94	42	37	2.03
Japanese birch	137	63	62	3.40
" "	157	82	54	2.19

the areas from where the seed was obtained. To have been hardy there, they undoubtedly came from parts of their range which had milder climates than Newfoundland. The height for the exotics is best compared with black spruce which would normally be used in reforestation in the area.

Black spruce averaged about 3 m after 15 years. Several pines - jack pine, lodgepole pine and Scots pine - were substantially taller. Red pine, although native to Newfoundland, grew slower than black spruce. The red pine did not originate in Newfoundland but since it is one of the least variable conifers it could be expected that the provenance tested would perform similarly to a local one (Fowler and Lester 1970, Klein 1976). One strain each of Sitka and Norway spruce were slightly taller than black spruce but the differences are not statistically significant. A later provenance trial of Sitka spruce with a black spruce provenance planted for comparison also showed that Sitka spruce either grew slower than black spruce or was not significantly different in growth from it at 10 years from seed (Khalil 1977). Sitka spruce also had much more winter damage than the local black spruce (Khalil 1977).

It can be concluded that the Japanese and European larches were the only exotics to show a superiority in height growth over the native species (Hall 1982).

North Pond, Central Newfoundland. This plantation was established on a site which had been clearcut then burned by wildfire six years before planting (Hall 1973). The area rapidly became stocked with black spruce, white birch, trembling aspen and pin cherry with the wetter sites dominated by alders (Alnus spp.). Many of the exotic species soon became overtopped and only the planted pines and larches were able to maintain themselves in the stand. Approximately ten years after establishment the site was cleared. However, by this time the planted spruces had become suppressed, thus no useful data could be obtained from them. This also applied to planted cedar, hemlock and Douglas fir. Since no comparison was available in the form of planted local species the black spruce regeneration was measured. Fifteen-year-old trees averaged 3.5 to 4.0 m in height. Three species which did not survive the first few years from planting and not included in Table 12 are Sugi, black locust and whitebark pine. Survival results indicate that western white pine is unsuitable for planting on the site. Survival among the exotic larches has been generally poor, mortality after the fifth growing season has been slight. It is likely that with greater care in establishment, survival would be better. This was found to be the case in a plantation of exotic larches in western Newfoundland in which survival after the first growing season was 98-100%.[10]

It can be concluded from the results that only jack pine and one of the strains of Japanese larch grew as well as the natural black spruce regeneration. Thus on similar sites in central Newfoundland only these species should be considered for reforestation in addition to black spruce.

Windsor Lake, Eastern Newfoundland. This plantation was established on a clearcut balsam fir site and subsequently left unattended. Thus, the area rapidly became overgrown with dense balsam fir regeneration which suppressed the planted trees (Hall 1973). Some of the sites were eventually cleared but only those with planted larches and black spruce yielded results (Table 13). Most mortality occurred in the first few years after planting. The larches were more difficult to establish than native black spruce but have, as in other plantations, outgrown them by a wide margin. Several other seedlots including Norway spruce and Austrian pine survived well but their growth was poor because of the severe competition from balsam fir regeneration. Therefore their value as reforestation species is in doubt.

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[10] Hall, J. Peter. 1981. Trials of exotic species. I. Growth and development 15 years from seed, II. Summary of 1981 planting. Env. Can., Can. Forest. Ser., NeFRC File Rep. #12, Study 7231. 14 p.

Table 12. Percentage survival 5 and 10 years after planting and average total height, 15 years from seed of trees planted at North Pond.

Species planted	Seedlot number	Percentage survival 5 years	Percentage survival 10 years	Average total height (m)
Red pine	14	43	38	1.27
Jack pine	23	100	93	3.27
Lodgepole pine	18	56	59	2.38
Western white pine	36	17	7	0.51
Scots pine	51	89	89	1.59
" "	55	91	80	1.93
" "	47II	91	84	1.24
" "	47III	100	93	1.84
" "	48I	100	100	2.22
Eastern larch	27	100	97	4.68
Japanese larch	129	38	27	3.03
" "	130	23	23	3.64
" "	139	26	23	2.45
European larch	102	66	49	2.16
" "	134	-	62	1.86
Japanese larch	137	97	56	1.96

Table 13. Percentage survival, 5 and 10 years after planting and average total height, 15 years from seed of trees planted at Windsor Lake.

Species planted	Seedlot number	Percentage survival 5	Percentage survival 10	Average total height (m)
Black spruce	25	94	92	1.68
Eastern larch	27	88	85	2.90
Japanese larch	129	29	27	2.52
" "	130	43	39	3.15
" "	139	11	8	2.87
European larch	102	41	39	2.90
" "	134	58	56	1.88

The results from these plantations have shown generally that the larches grow better than native spruces but may be difficult to establish. Several species of spruce and pine grow as well and are as easy to establish as native spruce.

In 1970-71 two plantation trials of exotic spruces were established; one in central Newfoundland near Gander, the other in western Newfoundland near Corner Brook (Figure 2).

The data from the central Newfoundland plantation indicate that black spruce has the best survival and growth (Table 14). Only the height differences among species were statistically different, however.

In the western Newfoundland plantation survival was lower but black spruce survived best. Survival of black spruce was not statistically greater than that of Norway spruce but was statistically different from all others. Black spruce was significantly taller than all other species. Both Norway and Sitka spruce were damaged by the spruce budworm when the plantations were five to seven years old. Black spruce was only damaged to a slight degree compared to Sitka and Norway spruce. Serbian spruce had little damage possibly because the trees were smaller than the black spruce and were less likely to be attacked (Hall 1977c).

The encouraging results from the species trials led to establishment of a replicated species trial of larch near Stephenville in western Newfoundland in 1976.[11] A local seed source of tamarack was not available at the time, therefore one from Ontario had to be used. Each seedlot was replicated ten times in nine-tree plots at a spacing of 2.0 m. The plantation was established on a balsam fir cutover from which the slash had been removed.

Growth of both seedlots of the hybrid larch has been significantly better than that of eastern larch (Table 15). Growth of Japanese larch was also superior to eastern larch but the difference was not statistically greater. These data show that there is good potential for exotic larches as reforestation species although they may require considerable care in establishment.

In 1972 several clones of Populus were established at the Pasadena Nursery in western Newfoundland to assess their growth under local conditions (Khalil 1976). Survival and growth two years after planting indicated that clones of the following species and hybrids are suitable for planting on cultivated sites - Populus alba L., P. balsamifera L., P. canescens (Ait.) sp., P. deltoides Marsh., P. grandidentata and the cultivar P. euramericana. Further results are awaited on these species so that their potential can be assessed.

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[11] Rowe, D.A. 1976. Larch species trial in western Newfoundland. Env. Can., Forest. Serv., NeFRC File Report. 7 p.

Table 14. Percentage survival after number of growing seasons and average total height 15 years from seed for spruce species trial.

Species planted	Origin	Percentage Survival					Average total height(m)
		1	2	2[1]	5	10	
Central Newfoundland Plantation							
Black spruce	Badger, central Newfoundland	93.5	92.7	99.0	97.8	97.1	1.65
Sitka spruce	Bella Coola, B.C.	93.0	88.8	97.7	92.7	82.2	1.23
" "	Kitimat, B.C.	93.8	91.8	100.0	95.3	84.4	1.34
Norway spruce	Vilppula, Finland	93.5	83.3	95.1	94.5	93.2	1.23
" "	Region VIII/16 Germany	71.9	71.9	88.8	79.4	73.4	1.07
Serbian spruce	Knuthenborg, Denmark	89.1	85.9	99.6	97.7	84.7	1.13
Oriental spruce	Svejbeck, Jutland, Denmark	92.8	86.2	97.2	91.9	78.6	.59
Hondo spruce	Hokkaido, Japan	69.0	59.1	72.4	65.9	45.3	.36
Western Newfoundland Plantation							
Black spruce	Badger, central Newfoundland	97.4	96.6	100.0	95.1	88.8	1.87
Sitka spruce	Bella Coola, B.C.	95.8	89.3	100.0	77.3	55.5	1.07
" "	Kitimat, B.C.	89.1	81.0	95.1	78.9	56.5	1.06
Norway spruce	Vilppula, Finland	91.4	77.6	95.3	83.1	69.0	1.61
" "	Region VIII/16 Germany	98.2	94.0	100.0	85.7	64.6	1.56
Serbian spruce	Knuthenborg, Denmark	94.8	77.9	94.8	61.2	41.9	.86
" "	Region VIII/16, Germany	95.6	78.1	92.4	69.8	38.3	.83
Hondo spruce	Hokkaido, Japan	58.9	28.4	32.0	0.8	0.0	-

[1]After the second growing season many dead trees were replaced.

Table 15. Percentage survival two and five years after planting and average total height eight years from seed in larch species trial.

Species planted	Origin	Seedlot No.	Percentage survival 2	Percentage survival 5	Average total height (m)
Eastern larch	Petawawa N.F.I., Ontario	565	97.8[1]a	97.8a	1.21b
Japanese larch	High Meadow Forest England	645	63.3c	50.0c	1.32bc
Hybrid larch	Newton Seed Orchard, Scotland	647	77.8b	67.8b	1.56a
" "	Mabie Seed Orchard, Scotland	438	84.4ab	83.3ab	1.49ac
Siberian larch	Krasnojarsk, U.S.S.R.	648	50.0d	43.3d	.92d
" "	" "	633	68.9bc	57.8bc	.62e

[1]Means followed by the same letter are not significantly different from each other at probability level 0.99 (Steel and Torrie 1960).

E. Trials of Exotics in Afforestation Studies

Extensive areas of bog, fen and barren occur in Newfoundland. Afforestation of similar sites in Scandinavia had encouraged the development of afforestation methods for these sites and exotic tree species were often used in addition to local black spruce in the trials.

(i) Barren lands

Several barren areas on the Avalon Peninsula were ploughed and planted in 1966-68 (Salter and Evans 1976). All of the plantations, except one, failed because of exposure and frost upheaval which killed nearly all the seedlings (Richardson 1968). The successful plantation was at Avondale where exposure was less and the existing ground vegetation prevented frost upheaval. Results of survival and height measurements (Table 16) show eastern larch and jack pine to have had the best survival and eastern larch to have the best growth. This site is a harsh environment compared to forested sites on the Avalon Peninsula and the rapid growth of eastern larch indicates that it would be quite suitable on similar sites (Hall 1977a, 1982). Jack pine also grew quite well and may also have some potential on these sites.

Table 16. Species planted, survival after 12 years and total height, 15 years from seed at Avondale.

Species planted	Origin	Percentage survival	Average total height
Black spruce	Badger, central Nfld.	46	1.20
White spruce	Guysborough Co., Nova Scotia	31	1.21
Eastern larch	" "	81	4.12
Jack pine	Northumberland Co., New Brunswick	90	3.28
Scots pine	Morayshire, Scotland	53	2.73

(ii) Peatlands

Peatland sites on the Avalon Peninsula and near Stephenville in western Newfoundland were ploughed using the 'Parkgate tine plough' in 1966-67 and were subsequently planted to pine, spruce and larch (Salter and Evans 1976). On the Avalon Peninsula, Scots pine survived well but grew very slowly (Hall 1971a). Several species of spruce – white, Norway, black, Serbian and Sitka – were also planted. These had poor survival and growth and were unsuitable for these sites because of the lack of available nutrients combined with exposure to wind and ice (Hall 1971a). The plantation established in western Newfoundland had better survival and growth (Table 17). Here, all planted species except Norway spruce had good survival but the only species to grow well was L. kaempferi which had also done well on other sites in western Newfoundland (Hall 1982). The exotic larches have grown much faster than the native species.

Table 17. Species planted, survival after 10 years and total height, 15 years from seed at Stephenville.

Species planted	Origin	Percentage survival	Average total height
Black spruce	Northumberland Co., New Brunswick	88.2	.53
Sitka spruce	Terrace, B.C.	79.5	.24
Norway spruce	Vilppula, Finland	49.0	.24
Japanese larch	Region VII, Germany	74.2	2.35
Scots pine	Kuorevesi, Finland	79.9	1.31

(iii) Fens

Because of the poor results attained in the afforestation of the peatlands in eastern Newfoundland, attempts were made to afforest nutrient rich fens which were thought to have more potential. One of these trials was established in 1971 by draining a fen near Millertown Junction in central Newfoundland (Richardson 1979). Black spruce, white spruce and white birch from Newfoundland sources, were planted along with Sitka spruce and lodgepole pine (Table 18). The results show better survival than was obtained in eastern Newfoundland trials (Hall 1971a) and comparable survival to that after 10 growing seasons on the Stephenville plantation (Table 17). Lodgepole pine had the poorest survival of the conifers. The height of the lodgepole pine was greater than that of the other species but survival decreased rapidly with time.

The fens have more available nutrients than the bogs and exposure to wind is less. This has resulted in better survival on fens but the hoped-for increased growth rate has not materialized in the early years of establishment.

Table 18. Species planted, survival after one and five years and average height eight years from seed on a fen near Millertown Junction.

Species planted	Origin	Percentage survival 1	5	Average total height 8 yrs. from seed (m)
Black spruce	Badger, central Nfld.	98.2	81.2	.30
White spruce	Pasadena, western Newfoundland	96.7	73.8	.17
White birch	North Pond, central Nfld.	94.6	16.0	.33
Sitka spruce	Terrace, B.C.	97.9	86.6	.22
Lodgepole pine	Hazelton, B.C.	99.1	52.6	.64

VI. CONCLUSIONS

In order to partially or fully supplant a local species with an exotic in reforestation programs, the exotic must have grown better to compensate for the increased cost of establishment and the biological risk associated with different environments. It also must be resistant to such damaging factors as frost, insects and diseases.

Many of the exotics studied were successfully established in plantations and grew as well as native species. These exotics include red pine, jack pine, Scots pine, lodgepole pine, Sitka spruce and Norway spruce. They did not, however, grow appreciably faster than native ones. The exotics were more susceptible to such damaging factors as frost on Sitka spruce, spruce budworm defoliation on Sitka and Norway spruce and Armillaria root rot on a variety of exotic spruces. Pines on the wetter sites in Newfoundland were damaged severely by root collar weevils and thus have little value as reforestation species on any but the drier sites.

The best growing exotics were Japanese larch and European larch in western Newfoundland. They outgrew native black spruce and white spruce and so far have not been damaged by local insects and diseases. They are, however, potentially susceptible to the larch casebearer and larch sawfly.

None of the exotics has proven to be universally superior to local ones for all sites and conditions in terms of growth and resistance to damaging factors. Therefore future reforestation programs in Newfoundland will continue to use mainly black spruce and white spruce. The exotics, where proven superior under specific conditions, could be used but should form only a small portion of the program.

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